

[54] SAFETY SYSTEM FOR HYDROFOIL CRAFT 3,745,959 7/1973 Coffey et al. .... 114/66.5 H

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[57] **ABSTRACT**

A hydrofoil craft having foils carried on struts, the struts being supported for pivotal movement relative to the hull of the craft and held in position during foil-borne operation by a substantially rigid restraining device. The restraining device constitutes a mechanical fuse device which holds the strut in place during normal operation but ruptures or yields in response to impact forces on the strut to permit the strut to pivot in case it should strike an object in the water during high speed operation. The pivotal movement of the strut reduces the dangerously rapid deceleration that would otherwise occur and minimizes structural damage to the craft.

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[51] Int. Cl.<sup>2</sup> ..... **B63B 1/30**

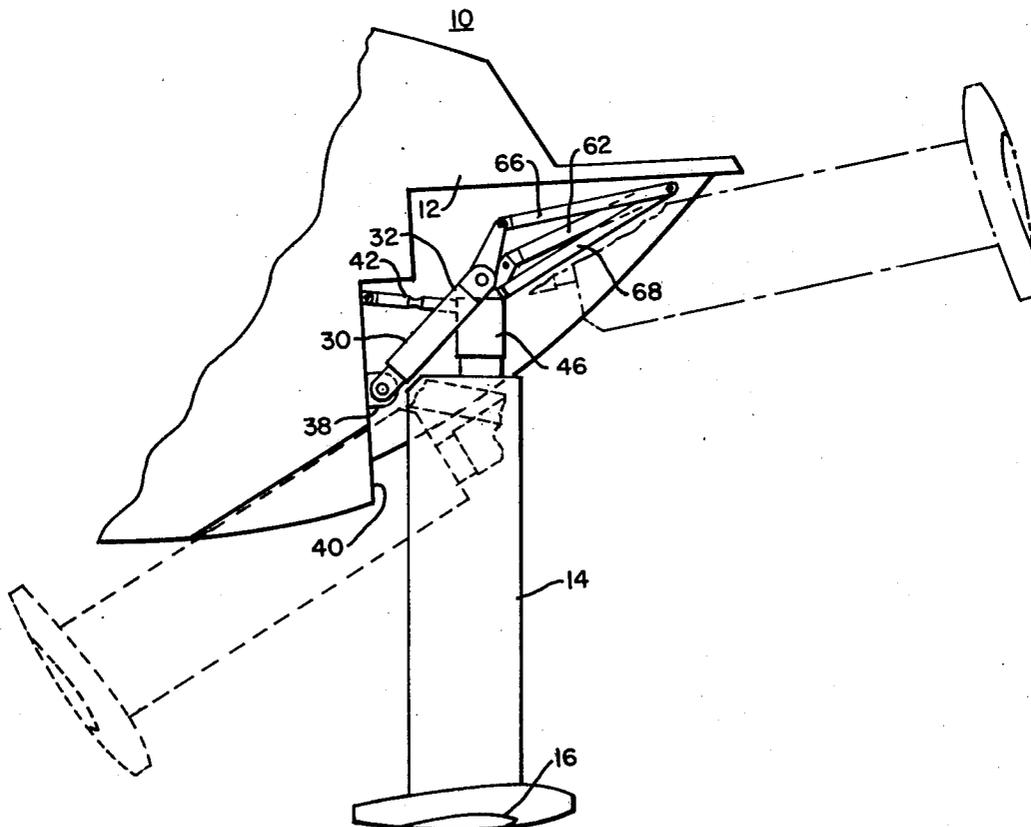
[58] Field of Search ..... 114/66.5 H

[56] **References Cited**

**UNITED STATES PATENTS**

2,771,051	11/1956	Von Schertel.....	114/66.5 H
2,795,202	6/1957	Hook .....	114/66.5 H
3,081,728	3/1963	Wilterdink et al.....	114/66.5 H
3,151,593	10/1964	Wennagel et al.....	114/66.5 H
3,294,052	12/1966	Jones .....	114/66.5 H
3,322,089	5/1967	Hook .....	114/66.5 H
3,465,704	9/1969	Baker.....	114/66.5 H

**5 Claims, 9 Drawing Figures**



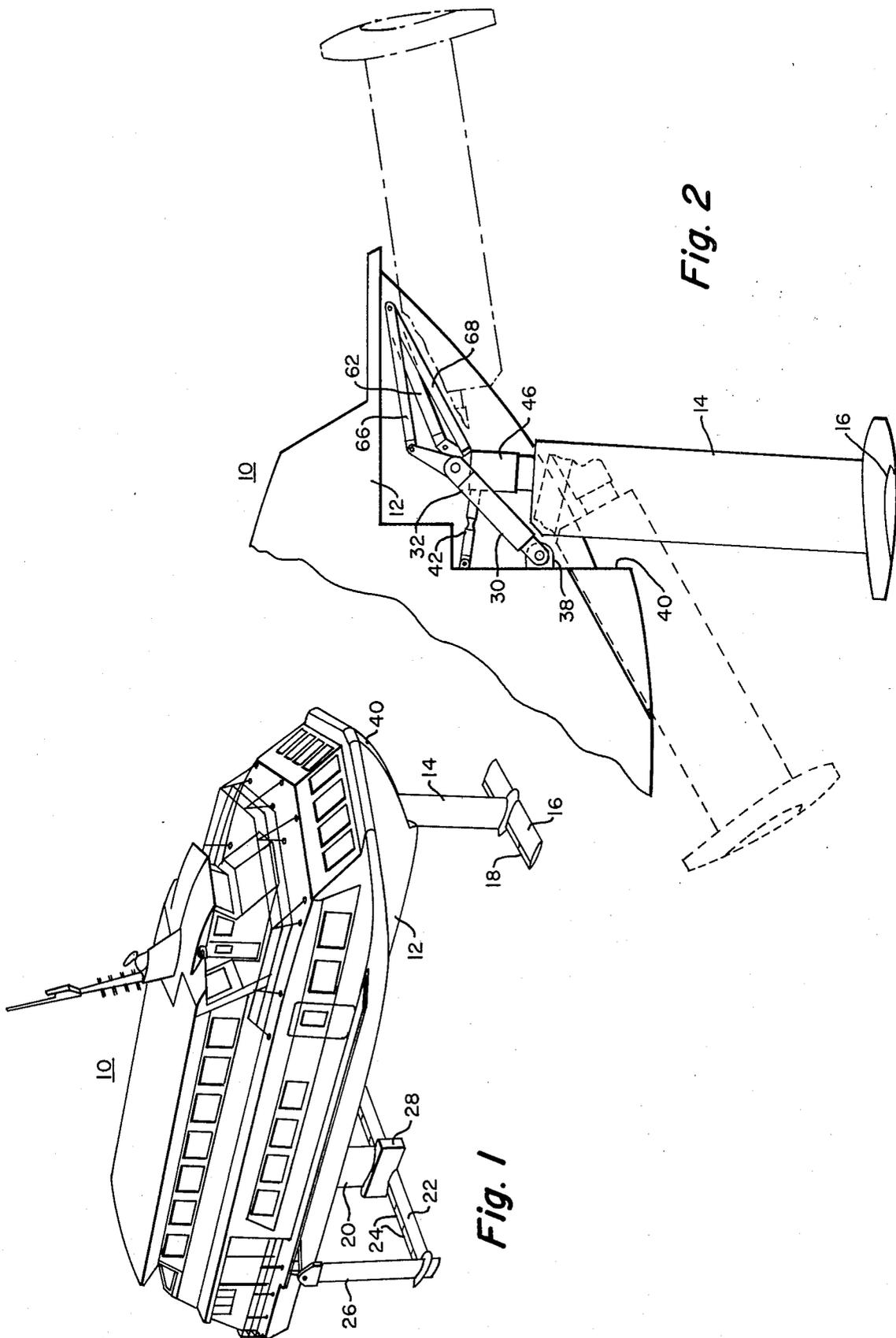


Fig. 1

Fig. 2

Fig. 4

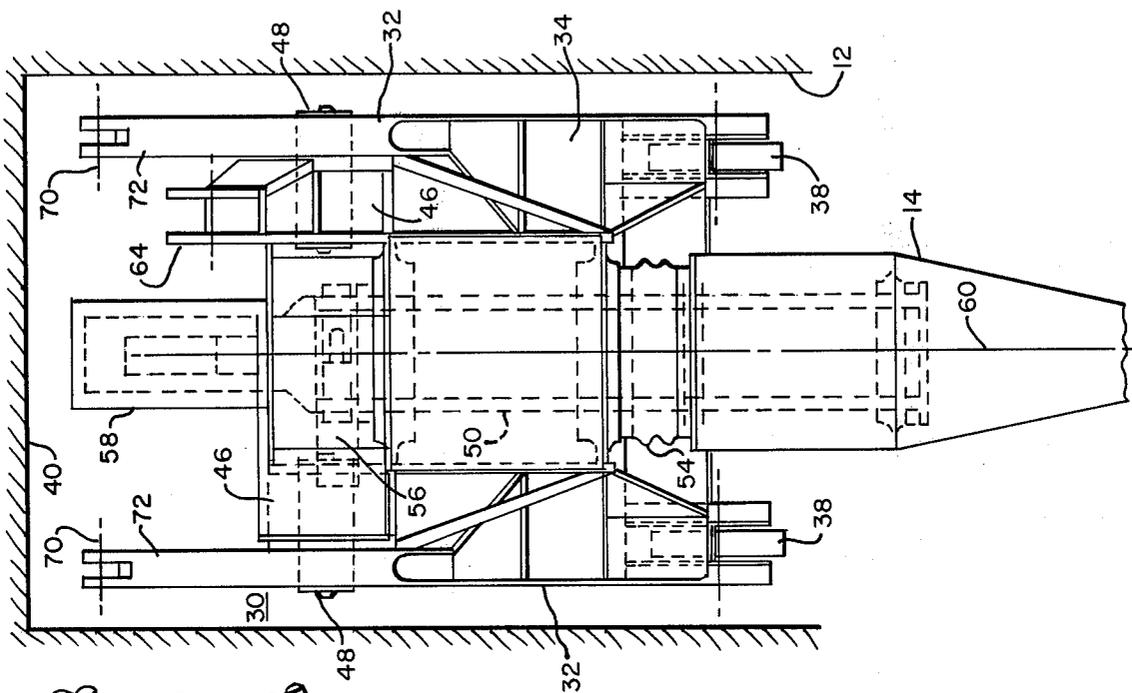
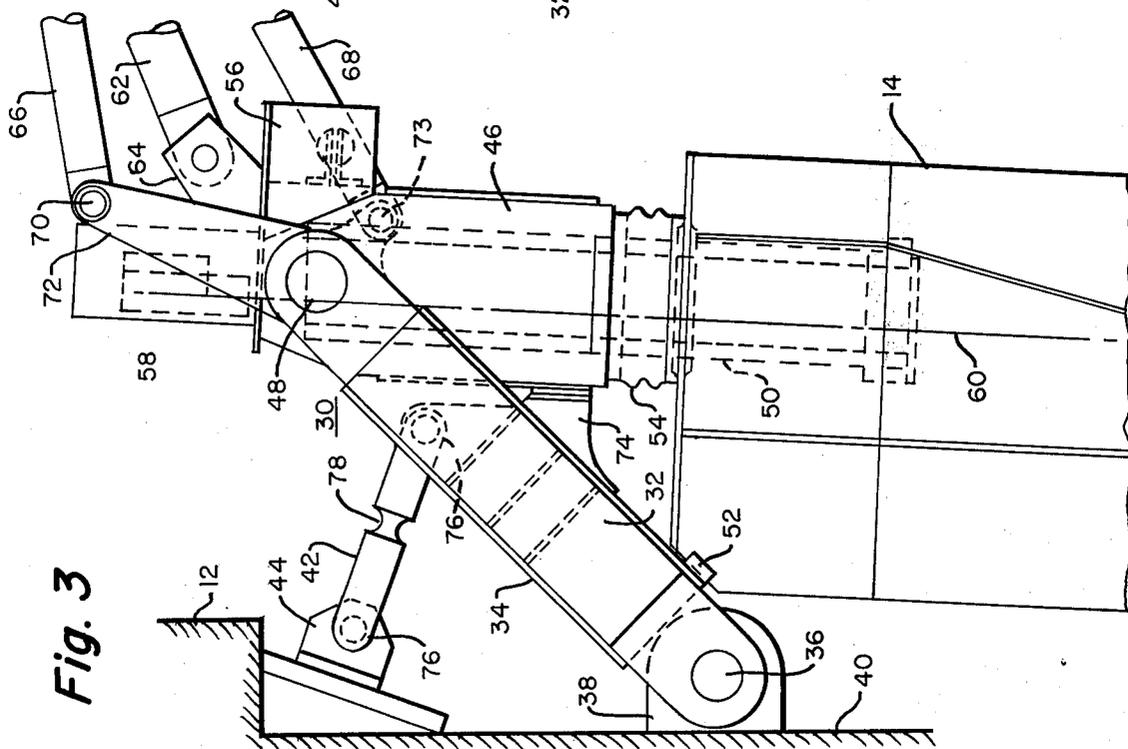


Fig. 3



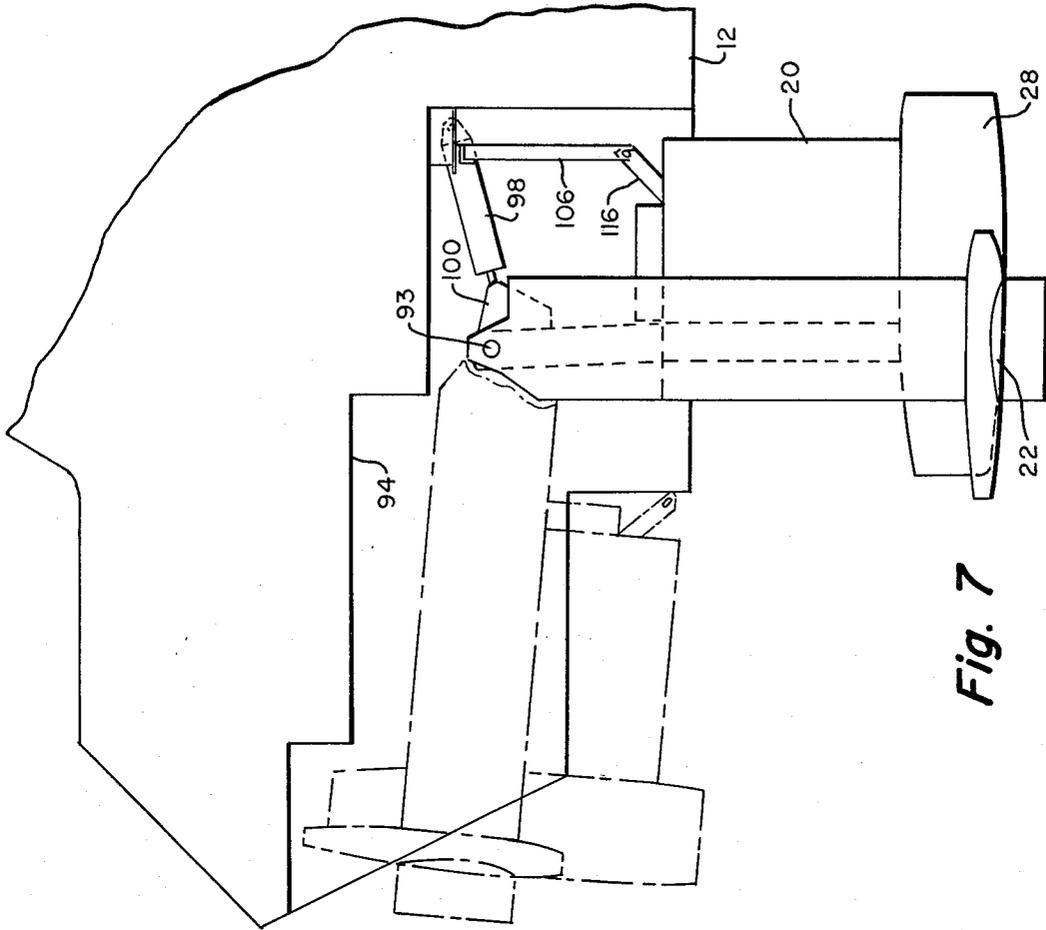


Fig. 7

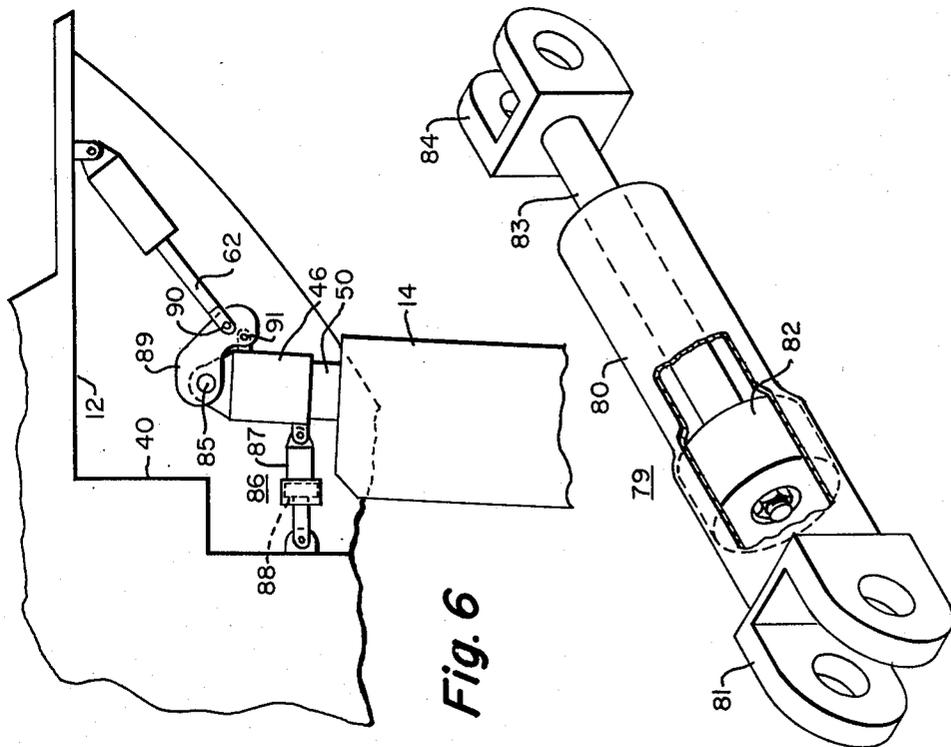


Fig. 5

Fig. 6

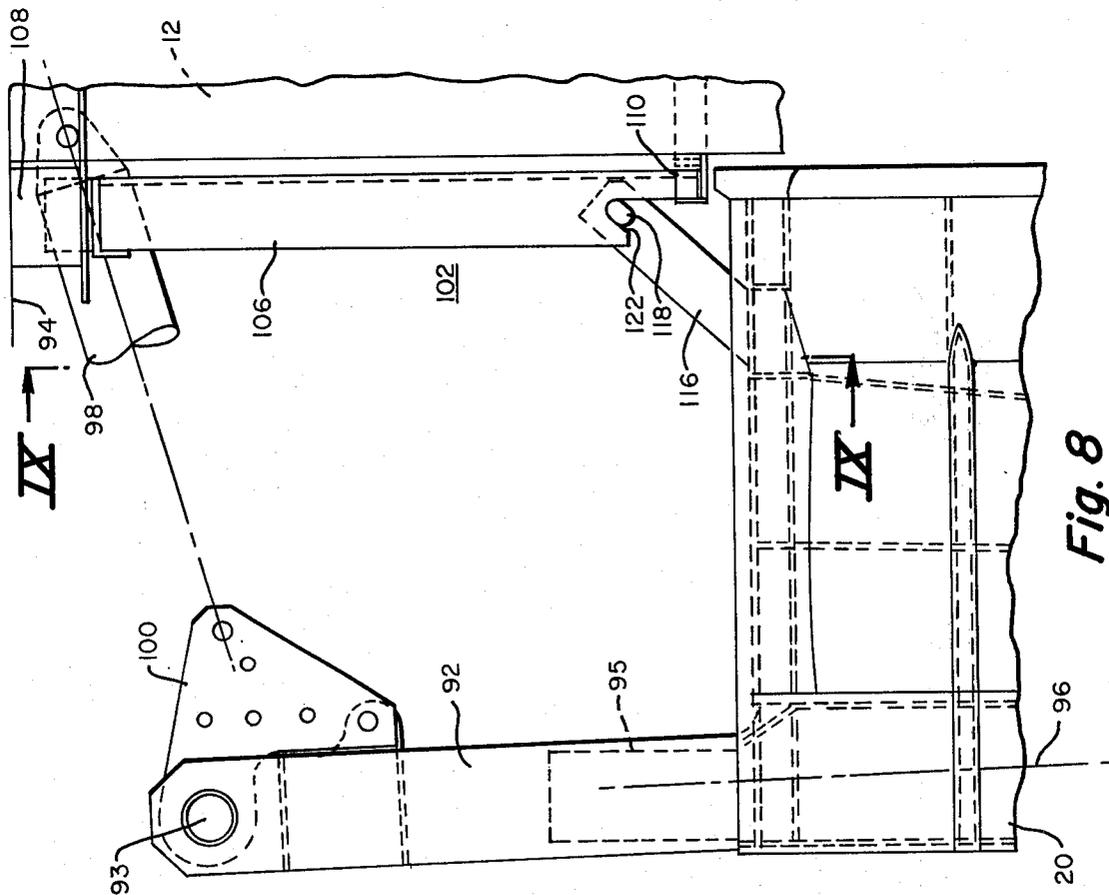


Fig. 8

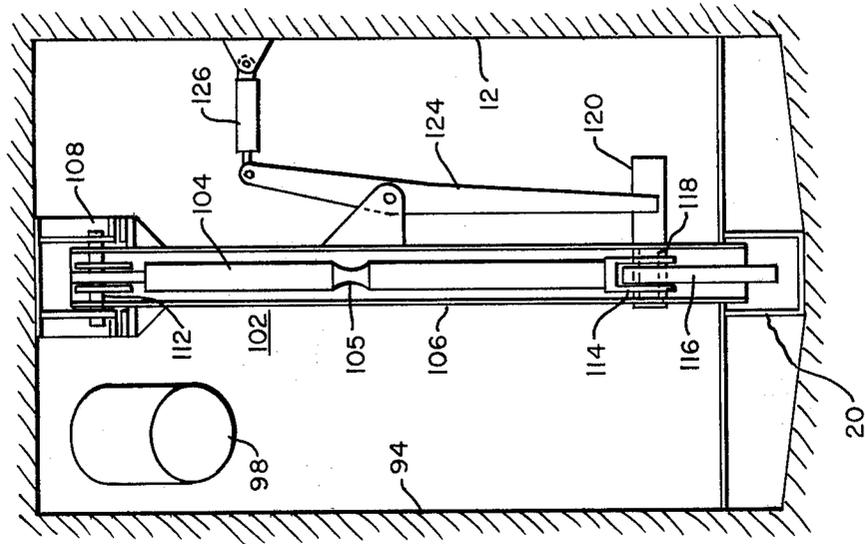


Fig. 9

## SAFETY SYSTEM FOR HYDROFOIL CRAFT

## BACKGROUND OF THE INVENTION

The present invention relates to hydrofoil craft, and more particularly to a safety support system for the foil-carrying struts.

Hydrofoil craft have foils which move through the water during flight, that is, during foil-borne operation of the craft, and develop lift in much the same manner as an airplane wing. The foils are carried on struts which are attached to the hull of the craft and hold the hull clear of the water during flight. The struts are usually mounted on the hull in a manner which permits the struts to be retracted so that the hull can float on the water and the craft can be operated in a hull-borne mode as a normal ship.

When foil-borne operation is desired, the struts are moved to their extended position and locked in place. In this mode of operation, very high speeds can be attained as compared with conventional ship speeds. These high speeds, however, involve a safety problem resulting from the possible presence of floating or submerged objects in the water in unexpected or unpredictable places. If one of the struts or foils strikes a sizable object of this kind, such as a floating log, for example, while traveling at high speed, the resulting impact forces result in an extremely rapid deceleration of the craft, and usually in damage to the foil-support system and to the hull structure itself. This abrupt deceleration between the time of impact and the time of becoming hull-borne as the craft settles on the water can be quite dangerous to passengers or crew members on board the craft. The structural damage may be quite extensive and may involve sufficient damage to the hull to result in a hazardous situation as well as requiring extensive repairs to the craft.

## SUMMARY OF THE INVENTION

In accordance with the present invention, a safety mounting support system is provided for the struts of a hydrofoil craft which limits or reduces the rate of deceleration resulting from impact forces caused by one of the struts or foils striking a floating or submerged object, and which limits or minimizes the possible structural damage by providing a predetermined failure path.

For these purposes, the struts are supported on the hull in a manner to permit pivotal movement in the aft direction but are normally held against such movement during foil-borne operation by substantially rigid restraining means. The forward strut is preferably mounted on a supporting structure in a manner to permit the strut to move relative to the supporting structure between the normal retracted and extended positions. The supporting structure itself is pivotally mounted on the hull and is held against movement in the aft direction by the rigid restraining means. The supporting structure may, however, be omitted and the forward strut pivoted directly on the hull and held by the restraining means. The aft strut is directly supported on the hull and when moved to the extended position for foil-borne operation, it is locked in that position by similar rigid restraining means.

The restraining means for both forward and aft struts is a substantially rigid structure or device which supports the strut in position against the forces encountered during normal operation. If an impact force, or a

force in excess of the normal load, is applied to this device, however, it is adapted to yield and permit pivotal movement in the aft direction. The yieldable restraining means or device may be of any suitable type. Thus it may be designed simply to rupture and release the strut entirely, or it may include an energy absorbing means which absorbs the impact energy while permitting the strut to move at a limited or controlled rate. In either case, the strut is permitted to swing in the aft direction in response to the impact force and thus reduce the abrupt deceleration which would otherwise occur, so that the craft can slow and settle onto the water at a safe rate of deceleration. The yieldable restraining means thus functions as a mechanical fuse device since it provides a predetermined failure path and permits the strut to move from its normal position by rupturing or failing in a predetermined manner. The mechanical failure is thus confined to an easily replaceable element or device and any other structural damage is prevented or minimized.

## BRIEF DESCRIPTION OF THE DRAWINGS

The invention will be more fully understood from the following detailed description of an illustrative embodiment, taken in connection with the accompanying drawings, in which:

FIG. 1 is a perspective view of a typical hydrofoil craft in which the invention may be utilized;

FIG. 2 is a view in side elevation, and partially in longitudinal section, of the bow portion of a hydrofoil craft showing the support of the forward strut;

FIG. 3 is a side elevation on a larger scale of the upper part of the forward strut and its support;

FIG. 4 is a view in front elevation of the structure shown in FIG. 3;

FIG. 5 is a perspective view of an alternative form of restraining means;

FIG. 6 is a somewhat diagrammatic view similar to FIG. 1 showing an alternative mounting for the forward strut;

FIG. 7 is a view in side elevation, and partially in longitudinal section, of the stern portion of a hydrofoil craft showing the support of the aft strut;

FIG. 8 is a side elevation on a larger scale of the upper part of the aft strut and its support; and

FIG. 9 is a view substantially on the line IX—IX of FIG. 8.

## DESCRIPTION OF THE PREFERRED EMBODIMENT

The invention is shown in an illustrative embodiment in a hydrofoil craft 10 which may be of any desired construction. As shown in FIG. 1, the craft 10 has a hull structure 12 of any suitable or usual design and is provided with a superstructure of any desired type which will not be described in detail as it is not a part of the invention. The hydrofoil 10 is provided with forward and aft foils which are carried on struts attached to the hull 12. Thus, a forward strut 14 is provided at the bow of the craft and carries a forward foil 16 of usual type which preferably has control surfaces 18 pivotally attached thereto. An aft center strut 20 is attached to the hull 12 at the stern portion thereof and carries an aft foil 22 of usual type which is provided with control surfaces 24 pivotally mounted thereon. Aft outboard struts 26 are preferably also provided, only the starboard outboard strut being visible in FIG. 1. The out-

board struts are pivotally mounted on the hull 12 to support the outer ends of the aft foil 22 but all control and actuating equipment is carried on the center strut 20 and the outboard struts 26 merely pivot with the center strut. The center strut 20 may include a water intake 28 which is part of a conventional propulsion system for use during foil-borne operation.

It will be understood that the invention is applicable to any other arrangement of struts and foils. Thus, for example, instead of the three aft struts shown, two independent struts each carrying an independent foil might be provided. Each strut would then carry its own control equipment and be mounted independently in the manner hereinafter described. Any other desired arrangement of struts and foils may of course be used.

The struts 14 and 20 are shown in FIG. 1 in their extended position for foil-borne operation, in which the foils move through the water and develop sufficient lift to support the hull 12 at a desired distance above the water. The control surfaces 18 and 24 are utilized to control the position and motion of the craft, and the forward strut 14 is preferably also rotatable about its vertical axis to serve as a rudder. For hull-borne operation of the craft 10, the struts 14 and 20 are moved to retracted positions so that the hull 12 floats on the water for operation as a conventional ship. The forward strut 14 moves pivotally in the forward direction in a slot or recess in the bow of the craft to the retracted position shown in dot-dash outline in FIG. 2, while the aft strut 20 moves in the aft direction in a recess in the hull to the dot-dash position shown in FIG. 6.

As previously discussed, a dangerous situation may occur if one of the struts 14, 20 or 26, or one of the foils 16 or 22, should strike a sizable floating or submerged object in the water during operation at high speed in the foil-borne mode. In accordance with the present invention, the struts 14 and 20 are supported and held in position in a manner to reduce the danger to passengers and crew and to minimize the risk of damage in this situation.

Referring first to the support for the forward strut 14 as shown in FIGS. 2-4, the forward strut and its associated control and actuating equipment are mounted on a support structure 30. The support 30 comprises two side arm members 32 connected by a frame portion 34 which joins the arms 32 together in a rigid structure of sufficient mechanical strength to support the strut 14. The arms 32 are pivotally mounted on pins 36 in brackets 38 attached to the rear wall of a recess 40 in the hull in which the forward strut 14 is movable in the forward and aft directions. The supporting structure 30 is thus rotatable about the pins 36 but is normally held against rotation by a restraining means 42, to be more fully described hereinafter, which connects the support 30 to a bracket 44 attached to the hull 12.

The forward strut 14 is supported at its upper end by a yoke member 46 which is pivotally mounted on the arms 32 of the support 30 on pins 48 journaled in bearings of any suitable type in the arms 32. The upper end of the strut 14 is secured to a kingpost member 50 supported within the yoke 46 and rotatable on bearings therein so that the strut 14 is angularly movable about its vertical axis to enable its use as a rudder as previously mentioned. The angular movement of the strut 14 is limited by stops 52 on each side carried on the frame portion 34 of the support 30, and the yoke 46 is connected to the top of the strut 14 by a flexible rubber

boot or seal 54 which is sufficiently flexible to permit the limited angular movement of the strut 14. A horizontal cylinder or servomotor 56 is carried on the upper part of the yoke 46 and connected to the kingpost 50 to move it angularly about the vertical axis. A second cylinder or servomotor 58 is mounted on top of the yoke 46 and actuates a linkage indicated at 60 which extends vertically down through the strut 14 to move the control surfaces 18 on the foil 16. The cylinders 56 and 58 are preferably controlled by electrical signals which may be transmitted to them from the cabin of the craft by flexible cables, or any other suitable means, so that there is no direct mechanical connection between the strut 14 with its associated equipment and the hull or other part of the hydrofoil craft.

As previously mentioned, the yoke 46 is pivotally mounted on the support 30 by means of the pins 48. The strut 14 and the yoke 46 comprise a unitary assembly which is pivotally movable between the extended position shown in solid lines in FIG. 2 and the retracted position shown extending forward in dot-dash lines. The actuating means for thus moving the strut 14 between extended and retracted positions may be of any suitable type and is also carried on the support 30. As shown in the drawing, the actuating means may consist of a cylinder or servomotor 62 pivotally attached to an upwardly extending bracket 64 on the yoke 46, so that operation of the cylinder 62 will move the yoke 46 to pivot the strut 14 about the pins 48. The actuating mechanism also includes upper and lower supports 66 and 68 on which the cylinder 62 is supported. The upper supports 66 are pivotally attached at 70 to upward extensions 72 of the arms 32, while the lower support 68 is attached at 73 to a bracket on the support 30. The cylinder 62 may be controlled in any desired manner, as by electrical signals transmitted through a flexible cable, or in any other desired manner not involving a mechanical connection to the hull. Movement of the strut 14 into the extended position may be limited by engagement of the yoke 46 with a fixed stop 74 on the support 30.

As previously mentioned, the support 30 is pivotally mounted at 36 on the hull 12 and is normally held against movement by a restraining member 42. In accordance with the present invention, the member 42 is designed to be a substantially rigid member or device which holds the support 30 and the strut 14 in position and restrains them from movement in the aft direction during normal operation in the foil-borne mode. If the strut 14 should strike a sizable object or obstruction in the water, however, so that a much higher than normal load, or an impact force, is imposed on the structure, the restraining member 42 yields and permits the entire support 30 with the strut 14 to pivot in the aft direction about the pins 36 to a position such as that shown in dotted lines in FIG. 2.

Any suitable member or device which can be designed to operate in this manner may be utilized, and if desired two members 42 might be used, connected to the side arms 32, for increased stiffness. In the embodiment of the invention shown in FIG. 3, for example, the restraining member 42 takes the form of a mechanical tension link which may be a steel bar of suitable size with pivotal mountings 76 at each end for connection to the bracket 44 and to the support 30, respectively, and with a reduced section 78 which is designed to rupture at a predetermined load. It will be seen that this

device will hold the support 30 and strut 14 rigidly in position under normal conditions but when subjected to an impact force, or other load in excess of the force for which it is designed, the member 42 will rupture at the reduced section 78 and release the support 30 so that the support and the strut 14 are free to pivot in the aft direction about the pivot pins 36. This permits the strut to yield upon striking an obstruction and prevents the rapid and dangerous deceleration that would otherwise occur as well as minimizing structural damage to the strut and to the hull.

In some cases, it may be desirable for the restraining means 42 to permit movement of the strut 14 at a controlled rate rather than to completely release it. For this type of operation, any suitable energy absorbing device may be utilized in place of the mechanical link 42 of FIG. 3. A suitable device 79 is shown, for example, in FIG. 5 and may consist of a steel tube or sleeve 80 having a pivotal connecting means or clevis 81 at one end thereof, with a cylindrical plug or mandrel 82 of larger diameter than the tube 80 mounted on a rod 83 extending through the tube 80 and having a clevis 84 at the other end thereof. The plug 82 is inserted into the tube 80 as shown and the device 79 may be mounted in place of the link 42 of FIG. 3 by attaching the clevises 81 and 84 to the bracket 44 and the support 30, respectively. Under normal operating conditions, the device 79 of FIG. 5 constitutes a rigid restraining structure which will hold the support 30 against movement. When subjected to impact forces, or other loads in excess of the force for which it is designed, the plug 82 will be drawn into and through the tube 80, stretching and deforming the tube and thus absorbing energy and permitting pivotal movement of the support 30 at a limited and controlled rate. The rate of deceleration resulting from impact of the strut 14 with a floating object is thus limited and controlled and the craft can descend to the hull-borne state in a relatively safe manner.

A somewhat simpler alternative mounting for the forward strut is shown in FIG. 6. As there shown, the forward strut 14 is supported in the yoke 46 as described above. The yoke 46 is pivotally mounted on pins 85 supported directly in the hull structure 12 on each side of the bow recess 40. The strut 14 is normally held in position by a restraining means 86 which is similar to the device 79 of FIG. 5 but reversed in operation since the device 86 is in compression. That is, the device 86 comprises a steel tube or sleeve 87 with a plug or mandrel 88 of larger diameter inserted in one end of the tube 87. The device 86 is pivotally attached as shown to the yoke 46 and to the hull 12 and normally holds the strut 14 in the position shown. Upon occurrence of impact forces, or other excessive forces on the strut 14, the plug 88 is forced into the tube 87, stretching and deforming the tube and permitting the strut to pivot in the aft direction about the pins 85 at a limited and controlled rate. Any other suitable restraining means may of course be used in place of the device 86.

The cylinder 62 which moves the strut 14 between retracted and extended positions is pivotally attached to the hull 12 in the FIG. 6 embodiment. A bell crank 89 is pivotally supported on the pin 85 on one side of the yoke and attached to the cylinder 62 by a pin 90. The bell crank 89 is connected to the yoke 46 for operation by a coupling pin 91 which is engaged to permit the cylinder 62 to move the strut from one position to

the other and disengaged when the strut is extended for foil-borne operation. The restraining means 86 is similarly connected at one end by a releasable pin to permit the strut to be moved to the retracted position when desired. Servomotors or other suitable control devices may of course be mounted on the yoke or strut in the manner shown in FIG. 3 for actuating control surfaces.

The aft strut 20 is mounted on the hull 12 in a manner to permit similar operation in case of impact of the strut 20 or of an outboard strut 26 with a sizable object in the water. As shown more particularly in FIGS. 7 to 9, the strut 20 has an upward extension 92 which is pivotally mounted on the hull structure 12 on a pivot pin 93. The strut 20 is thus pivotally movable in a recess 94 in the stern portion of the hull 12 between the extended position shown in solid lines in FIG. 7 and a retracted position shown in dot-dash lines. A cylinder or servomotor 95 may be mounted on or in the upward extension 92 for operating a linkage indicated at 96 extending through the strut 20 to actuate the control surfaces 24. An actuating cylinder 98 is pivotally attached to the hull structure 12 and connected to a bracket 100 at the upper end of the extension 92 to move the strut 20 about the pivot pin 93 between the extended and retracted positions. The actuator cylinder 98 may be controlled in any usual or desired manner, and is arranged in a known manner to be decoupled from the strut 20 when the strut has been moved to its extended position.

The strut 20 is held in the extended position by a restraining means 102 which locks it in place under normal conditions but is adapted to yield and permit movement of the strut under impact forces. The restraining means 102 as shown in FIG. 9 comprises a mechanical link 104 which may be similar to the link 42 of FIG. 3, having a reduced section 105 adapted to rupture at a predetermined load. The link 104 is contained in a semicylindrical housing 106 which extends downward from a bracket 108 attached to the hull 12. The lower end of the housing 106 is attached to the hull at 110. The link 104 is pivotally mounted at 112 in the upper end of the housing 106, while the lower end of the link has a clevis 114 adapted to receive a lug 116 extending upward from the strut 20. The lower end of the link 104 is normally attached to the housing 106 by a locking pin 118 which is movable in a housing 120 and is received in a recess 122 in a cut-away portion at the bottom of the housing 106. The pin 118 passes through the clevis 114 to position the link 104 and to normally attach the lower end of the link to the housing by engagement of the pin 118 in the recess 122. The pin 118 also passes through a hole in the lug 116 to lock the lug to the link 104 and housing 106, and the pin 118 is movable in the housing 120 far enough to retract it to allow the lug 116 to move in and out of the clevis 114. The pin 118 is movable by a lever 124 actuated by a cylinder 126 which is controlled from the strut retraction control in any desired manner.

In normal operation, when the strut 20 is moved to the extended position, the lug 116 is locked to the restraining means 102 by the mechanism just described and the strut is solidly held in position. Under an impact force, however, or other higher load than normal, such as may occur if the strut 20 or either of the outboard struts 26 strikes a floating object, the force on the link 104 exceeds the value for which it is designed and the link will rupture at the reduced section 105. This permits the strut 20 to swing free since the pin 118

can slide out of the recess 122 when the link has ruptured, and the lever 124 has a forked end to allow the pin to move downward free of the level 124. Thus, the strut 20 can pivot about the pin 93 to or near the full retracted position. If limited and controlled movement of the strut 20 is desired rather than complete release, the tension link 104 can, of course, be replaced by an energy absorbing means such as that shown in FIG. 5. Under an impact load, such a device will yield sufficiently to allow the pin 118 to slide out of the recess 122 and the energy absorber pivots out of the housing 106 about the pivot 112 and is stretched to control movement of the strut as previously described. If independent aft struts are provided, as previously mentioned, each strut will be mounted on the hull as just described.

It will be seen that both the forward and aft struts are mounted and supported in such a manner that they are rigidly held in position under normal conditions for foil-borne operation of the craft. In case of impact of any strut or foil against a floating or submerged object of dangerous size, the restraining means will yield and permit the strut to move in the aft direction so that the craft is not brought to an abrupt stop. The extremely high rate of deceleration which would otherwise occur is thus reduced sufficiently to eliminate, or at least greatly reduce, the hazard to passengers and crew on the craft. The aft strut is free to pivot essentially to its normal retracted position so that little structural damage can occur. The forward strut moves aft until it strikes the hull, as indicated in FIG. 2, but the resulting impact is relatively light, especially if an energy absorbing restraining means is used, and any damage is relatively small. It will be seen, therefore, that a safety system has been provided which will reduce the rate of deceleration to a safe amount in case the craft should strike a floating object, and which will substantially eliminate or at least minimize any structural damage to the craft.

Since the restraining means is designed to yield at the desired load to release the strut, a predetermined failure path is built into the structure, and the restraining

means acts in effect as a mechanical fuse device which fails under predetermined conditions to protect the structure. The mechanical failure is thus confined to an easily replaceable element or device and any other structural damage is prevented or minimized.

I claim as my invention:

1. In a hydrofoil craft having a hull structure and forward and aft struts carrying foils, a support structure for said forward strut, said support structure being pivotally mounted on the hull structure for movement in the aft direction, the forward strut being pivotally mounted on the support structure for movement relative to the support structure in the forward direction between a retracted position for hull-borne operation of the craft and an extended position for foil-borne operation, and means for restraining the support structure against pivotal movement, said restraining means being a substantially rigid structure adapted to hold the supporting structure against movement under loads below a predetermined value and to yield and permit movement of the support structure and forward strut in response to loads above said value.

2. The combination of claim 1 in which said rigid structure is adapted to rupture and release the supporting structure in response to loads above said predetermined value.

3. The combination of claim 1 in which said rigid structure comprises energy absorbing means adapted to yield and permit pivotal movement of the supporting structure at a limited rate in response to loads above said predetermined value.

4. The combination of claim 1 and including means carried on said supporting structure for moving the forward strut between said retracted and extended positions.

5. The combination of claim 4 in which the foil carried by said forward strut includes control surfaces, and actuating means carried on the supporting structure for effecting movement of said control surfaces and limited angular movement of the strut about its axis.

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